(2)

TARDEC

Technical Report

No. 13586

TRACK PIN TESTING PROCEDURE

HAMMER RING TEST EVALUATION

1993

Martin P. Laurain
U.S. ARMY TARDEC
AMSTA-RTT
Warren, MI 48397-5000

U.S. Army Tank-Automotive Command
Research, Development, and Engineering Center
Warren, Michigan 48397-5000

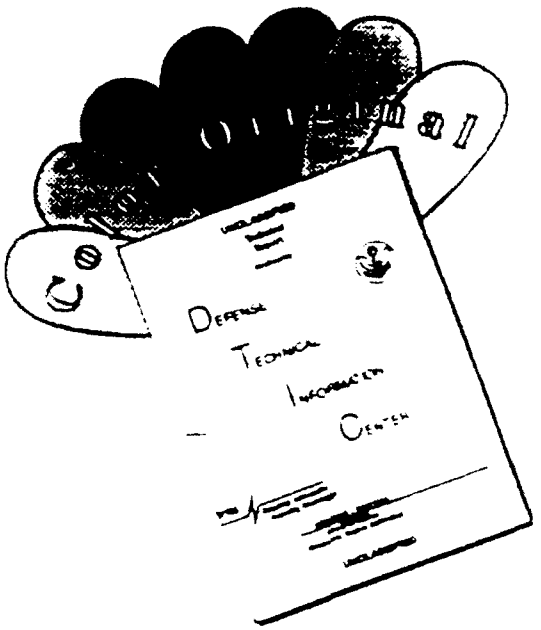
NOTICES

This report is not to be construed as an official Department of the Army position.

Mention of any trade names or manufacturers in this report shall not be construed as an official endorsement or approval of such products or companies by the U.S. Government.

Destroy this report when it is no longer needed. Do not return it to the originator.

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Track Pin Testing Procedure
Hammer Ring Test Evaluation

5. FUNDING NUMBERS

6. AUTHOR(S)
Martin P. Laurain

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Tank-Automotive Research Development
& Engineering Center
Track Technology Branch (AMSTA-RTT)
Warren, MI 48397-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The hammer ring test procedure needed to be evaluated to determine its accuracy and effectiveness. The results of the evaluation determined if the test procedure would be reinstated into operator manuals for heavy track tanks. The evaluation was conducted at the Keweenaw Research Center in Houghton, MI by government employees from the Track Technology Group, Maintenance Group and Logistics. The hammer ring test, in fact, provided poor crack detection ability and is not recommended to be reinstated in the operator manuals. The evaluation includes promising ultrasonic detection results for detecting cracked pins, however, and it is recommended that the ultrasonic detection system be considered for future testing.

14. SUBJECT TERMS

15. NUMBER OF PAGES
39

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	Same as Report

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FIGURES

TABLES

1.0 INTRODUCTION

The hammer ring test, used for checking track pins for cracks, was evaluated through an experiment at the Keweenaw Research Center in Houghton, MI. Five government employees, with the assistance of KRC personnel, performed the tests and provided data for the evaluation. The hammer ring test complied with operator manuals for the M1A1, TM 92350264210-1 and for the M1 & IPM1, TM 9235025510-1.

1.1 Background

The hammer ring test was removed from the operator's manual in September, 1990 as a result of a directive that began in 1979. The reasoning behind this decision was that the hammer ring test was not a valid and conclusive means of detecting cracked pins on heavy tracked vehicles. Recently, however, due to a few unfortunate accidents in Europe, there has been an inquiry into the appropriate operators manual inspection procedures regarding tank track. Because of the apparent need for an inspection procedure to check for cracked track pins, the hammer ring test was to be re-evaluated. Because there had never been a recognized, official test evaluation for the hammer ring test, the need for new experimentation to evaluate the test was determined. The experiment description and findings are presented in the Test Procedure and Results portion of this report.

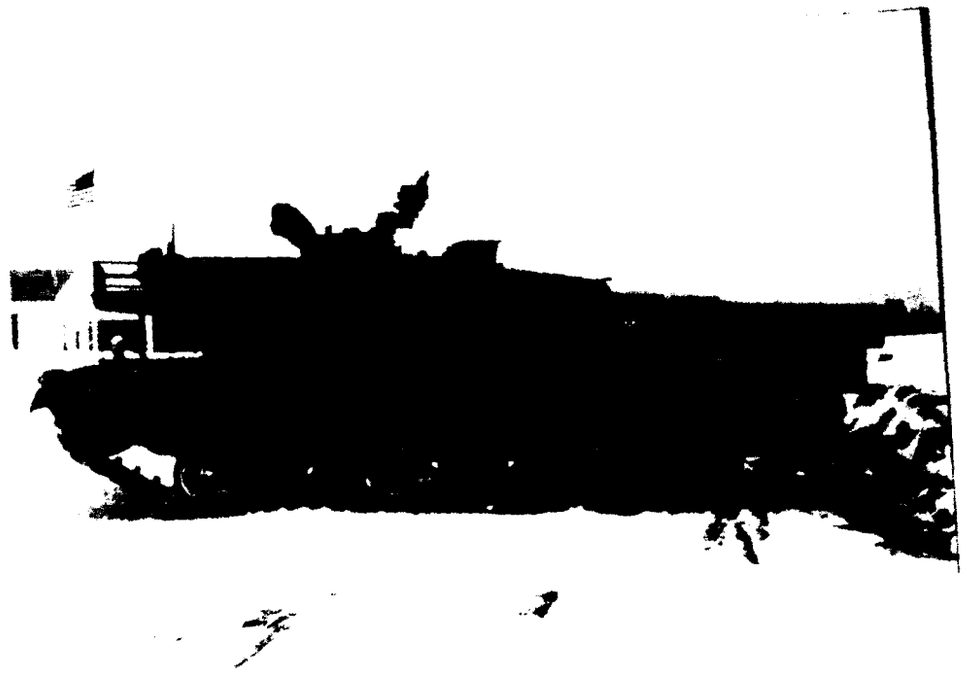
1.2 objective

The primary objective of the experiment at KRC was to determine the accuracy and effectiveness of the hammer ring test. The goal was to acquire enough data from the group to reach a conclusion on the test and its ability to find cracked track pins.

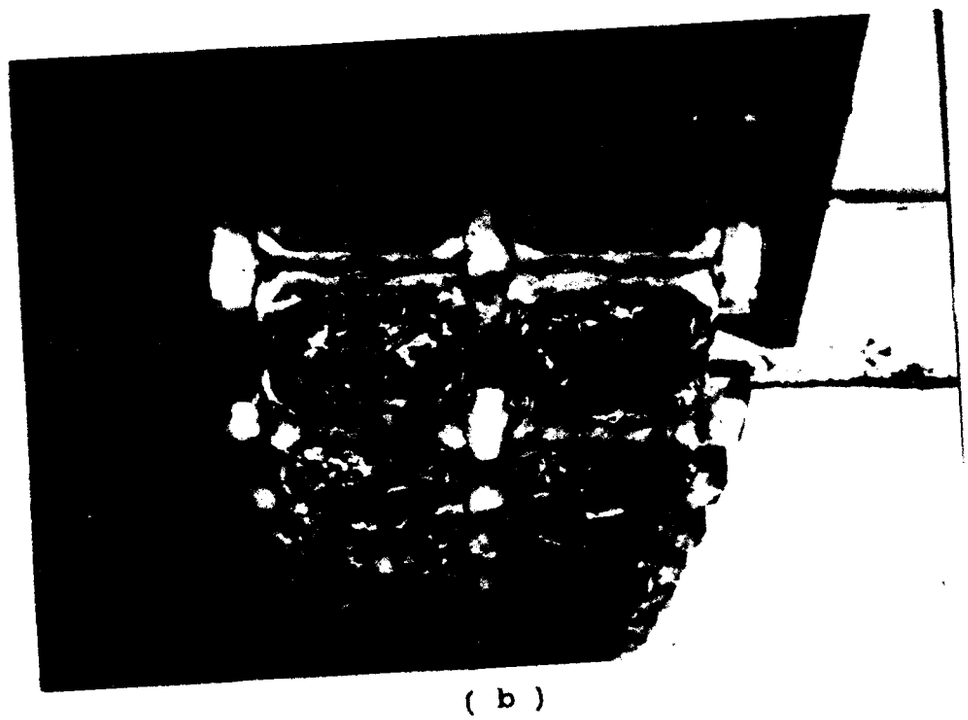
Secondly, the group was given a chance to check the same strands of track using ultrasonic equipment. The group had minimal training on the equipment before testing the track. The goal was to obtain information on the ultrasonic equipment, which could then be compared with the hammer ring data, and possibly lead to future considerations for new testing procedures for the Army.

2.0 PROCEDURE

The hammer ring test and the ultrasonic sound test procedures were evaluated on the same track on the same vehicle. A picture of the tank and T158 track is shown in Figure 2.1. An example of a cracked pin is shown in Figure 2.2. These large cracks shown at the bottom of this pin are the types of cracks that these test procedures attempt to detect before they become larger and



(a)



(b)

Figure 2.1a. M1A1 Tank Used For Testing at the Keweenaw Research Center.

2.1b. Similar T158 Track Used For Test Evaluation.

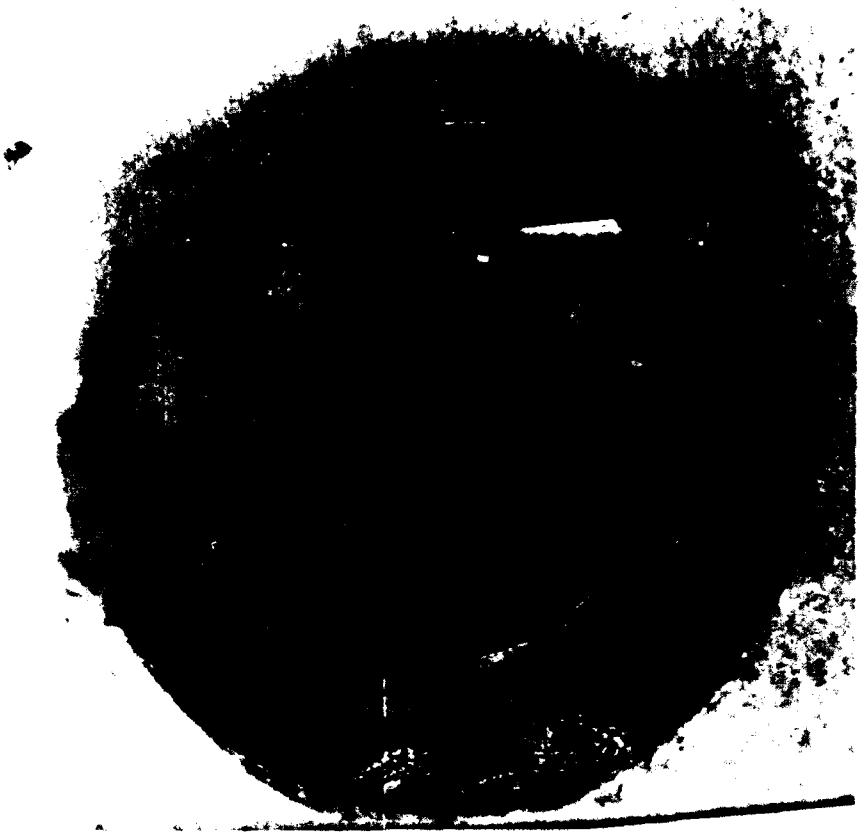


Figure 2.2. Cross Section of Track Pin Showing Large Cracks at the Bottom.

possibly result in the pin breaking completely. The following describes the experiment procedures conducted by KRC and the five government employees.

2.1 Initial Preparation

To prepare for the test, the Keweenaw Research Center, KRC, of Michigan Technological University worked closely with members of the Tank-Automotive Research, Development and Engineering Center (TARDEC) Track Technology group to assure all requirements were met. First, KRC obtained two strands of first generation T158 track. These strands consist of the new shoe body design with replaceable pads but use T156 track pins and connectors. The two strands were mounted on an M1A1 tank located at KRC. Technicians there torqued all the connectors, drove the vehicle approximately 10 miles to seat the track, then retorqued all connectors to assure the track was ready for testing.

The two strands were identified as right and left, pertaining to the side of the tank. Each strand was labeled by track shoes 1 through 78 and by pin, A & B, totaling 156 pins per strand. Each pin of both strands was inspected with an ultrasonic unit to determine their status. The inspectors at KRC have extensive experience in ultrasonics and their expertise was utilized to develop the master chart of all the pins. This information, however, was not given to the members of the group until after the experiment and all pertaining data was collected.

2.2 Hammer Ring Test Procedure

As stated, the first phase of the experiment was the hammer ring test. The test consisted of each member of the five member group checking each pin thoroughly. The hammer ring process is such that an inspector strikes a track pin with a ball peen hammer and listens to the tone. If a ring tone is produced, the pin is acceptable. If a dull tone or thud results, a cracked pin or loose component is the cause. Because all the end connectors were carefully tightened before the test, the inspectors assumed the pin was cracked, and recorded as such. The data was recorded by the five members, condensed, and is presented as raw data of the hammer ring test in Appendix A. Analysis of data will be discussed in the Results section of the report.

2.3 Ultrasonic Test Procedure

The second portion of the experiment was to perform an ultrasonic inspection of the track pins by the five member group. After the brief training and demonstration of the equipment, the group proceeded to individually inspect each pin with the ultrasonic equipment.

To inspect a track pin with the ultrasonic unit, the operator must first clean the transducer and the end surface of the pin. Next, a sound-conducting jelly is applied to both the tranducer and the end surface of the pin. The transducer is then pressed firmly against the end of the pin. For a track pin, a sound wave is transmitted down the length of the pin and received by the same transducer. If a crack exists in the pin, the sound wave detects the flaw and is represented by a sharp spike in the signal on the display screen. Data was collected for each member the same way as the hammer ring data, identifying each pin as cracked or not cracked. This data was condensed and is displayed in Appendix B as raw data for the ultrasonic test. Further analysis of this data is discussed in the following Results section.

3.0 RESULTS AND DISCUSSION

The hammer ring test evaluation did not prove to be an effective way to check for cracked track pins. Ultrasonic testing, however, provided more accurate results and may have proved to be a method for future consideration. The hammer ring and ultasonic test data, listed in the appendices, will be analyzed separately, showing the effectiveness of each.

3.1 Hammer Ring Test Analysis

As previously stated, Appendix A contains the raw data taken from the hammer ring test. The charts consist of the pin numbers, crack status/location and how each member recorded each pin. This data shows the inconsistency and inaccuracy obtained from the five-member group.

The first summation of this data is shown in Table 3.1, which consists of only the 21 cracked pins present on the two strands. The strand and pin number are listed, as well as the size of the crack, crack location and how each member identified these pins. For these cracked pins, the group's efforts were quite consistant. However, the group was not very accurate in their testing for cracked track pins. From this data in Table 3.1, a brief summary of the group's ability to locate various sized cracks is listed below. For the identification of small to large cracked pins, the five members were very inaccurate, as seen by these percentages:

Broken Pins	9 of 10	90%
Large Cracks	16 of 30	53%
Medium Cracks	5 of 20	25%
Small Cracks	0 of 55	0%

The previous data only discusses the group's performance of those 21 cracked pins. It shows the group's failure to identify cracked pins but does not consider the good pins which some thought were bad. The following analysis of data discusses the probability of a particular event for the entire scope of the 312 track pin population. This analysis of data discovers the probability of error and the probabilty of correct decisions for the entire sample. The probability types are listed in as follows:

E1 = Probability that a good pin is rejected
E2 = Probability that a bad pin is accepted
P1 = Probability that a good pin is accepted = 1 - E1
P2 = Probability that a bad pin is rejected = 1 - E2

Pin Number	Size of Crack	Crack Location	Member 1	Member 2	Member 3	Member 4	Member 5
R 10A	Small	Inboard	N	N	N	N	N
R 25B	Medium	Center	N	N	N	N	N
R 26B	Broken	Center	Yes	Yes	Yes	Yes	N
R 27A	Medium	Inboard	Yes	Yes	Yes	Yes	Yes
R 29B	Large	Center	Yes	Yes	Yes	Yes	Yes
R 30B	Large	Center	N	N	N	N	N
R 31B	Small	Center	N	N	N	N	N
R 34A	Large	Center	Yes	Yes	Yes	Yes	Yes
R 35A	Large	Center	N	Yes	N	N	N
R 42B	Small	Outboard	N	N	N	N	N
R 47B	Small	Center	N	N	N	N	N
R 56A	Small	Center	N	N	N	N	N
R 71A	Broken	Outboard	Yes	Yes	Yes	Yes	Yes
R 72A	Small	Center	N	N	N	N	N
L 14A	Small	Center	N	N	N	N	N
L 22B	Small	Outboard	N	N	N	N	N
L 23A	Small	Outboard	N	N	N	N	N
L 29B	Medium	Center	N	N	N	N	N
L 38A	Large	Center	N	N	N	N	N
L 39A	Medium	Center	N	N	N	N	N
L 43B	Large	Center	Yes	Yes	Yes	Yes	Yes
L 47A	Small	Center	N	N	N	N	N
L 58A	Small	Center	N	N	N	N	N

Table 3.1. Data Summation of 21 Cracked Pins and How They Were Identified During the Hammer Ring Test.

The probability that a good pin is rejected, E1, will be relatively low in this experiment primarily because of the sample size. There is a total of 291 good pins versus only 21 cracked pins. Inversely, the probability of a good pin being accepted is going to be extremely high due to the formula P1 = 1 - E1. The two probabilities that are presented in the data summation Table 3.2, are E2 and P2. These are the most relavent because they represent the group's probability of locating cracked pins with the hammer ring test. In Table 3.2, the numbers for E2 show a high probability that a cracked pin will not be found. Inversely, P2 represents a low probability that bad pins are found.

The results of this hammer ring test evaluation do not provide much accuracy or effectiveness for locating cracked track pins. Further discusion of this experiment is presented in the Experiment Discussion at the end of this section and in the Conclusions and Recommendation portion of this report.

3.2 Ultrasonic Sound Test Analysis

The ultrasonic detection system for locating cracked track pins provided better results for the group. The data acquired from this test is listed in Appendix B in the same format as the hammer ring data. All ultrasonic data is analyzed and presented the same as the previous section so that the two tests could easily be compared.

First, the data for the 21 cracked pins was condensed and listed in Table 3.3. The group maintained the same level of consistency but improved their accuracy tremendously. The summation of this data (below) shows the improved percentages for detecting cracked pins:

Broken Pins	8 of 10	80%
Large Cracks	26 of 30	87%
Medium Cracks	6 of 20	30%
Small Cracks	17 of 55	31%

Specific improvements were made in the detection of large and small cracks which increased from 53-87% and 0-31% respectively over the hammer ring test.

The probabilities for the entire scope of the sample size also improved. The same four probabilities are used to describe the results. Table 3.4 focuses on E2, the probability a bad pin is accepted, and P2, the probability a bad pin is rejected (1 - E2). These numbers also made supstantial improvements over the hammer ring method. The group's probability to locate cracked pins increased in average from .243 to .493.

Right Hand Side

Sample Size = 156 track pins
Actual Number of Cracked Pins = 14
Let E2 = The Probability That A Bad Pin Is Accepted
Let P2 = The Probability That A Bad Pin Is Rejected

	Identified Defective	Identified Defective Actually Defective	E2	P2
Member 1	17	5	9/14 = .643	5/14 = .357
Member 2	28	6	8/14 = .571	6/14 = .429
Member 3	26	5	9/14 = .643	5/14 = .357
Member 4	16	5	9/14 = .643	5/14 = .357
Member 5	22	3	11/14 = .786	3/14 = .214

Left Hand Side

Sample Size = 156 track pins
Actual Number of Cracked Pins = 7
Let E2 = The Probability That A Bad Pin Is Accepted
Let P2 = The Probability That A Bad Pin Is Rejected

	Identified Defective	Identified Defective Actually Defective	E2	P2
Member 1	15	1	6/7 = .857	1/7 = .143
Member 2	17	1	6/7 = .857	1/7 = .143
Member 3	14	1	6/7 = .857	1/7 = .143
Member 4	8	1	6/7 = .857	1/7 = .143
Member 5	13	1	6/7 = .857	1/7 = .143

Table 3 2. Probability Data Summation For the Entire Population of Hammer Ring Test Data.

Pin Number	Size of Crack	Crack Location	Member 1	Member 2	Member 3	Member 4	Member 5
R 10A	Small	Inboard	N	N	N	N	N
R 25B	Medium	Center	Yes	Yes	Yes	Yes	Yes
R 26B	Broken	Center	Yes	Yes	Yes	Yes	Yes
R 27A	Medium	Inboard	N	N	N	N	N
R 29B	Large	Center	Yes	Yes	Yes	Yes	Yes
R 30B	Large	Center	Yes	Yes	Yes	Yes	Yes
R 31B	Small	Center	Yes	Yes	Yes	N	N
R 34A	Large	Center	Yes	Yes	Yes	Yes	Yes
R 35A	Large	Center	N	Yes	Yes	Yes	Yes
R 42B	Small	Outboard	N	Yes	N	N	N
R 47B	Small	Center	N	Yes	Yes	Yes	Yes
R 56A	Small	Center	-	Yes	N	Yes	Yes
R 71A	Broken	Outboard	Yes	Yes	Yes	N	N
R 72A	Small	Center	N	N	N	N	N
L 14A	Small	Center	Yes	N	N	N	N
L 22B	Small	Outboard	N	N	Yes	N	N
L 23A	Small	Outboard	N	N	N	N	N
L 29B	Medium	Center	N	N	Yes	N	N
L 38A	Large	Center	Yes	Yes	N	N	N
L 39A	Medium	Center	N	N	N	N	N
L 43B	Large	Center	Yes	Yes	Yes	Yes	Yes
L 47A	Small	Center	N	N	N	Yes	N
L 58A	Small	Center	Yes	Yes	Yes	N	N

Table 3.3. Data Summation of 21 Cracked Pins and How They Were Identified With the Ultrasonic Test.

Right Hand Side

Sample Size = 156 track pins
Actual Number of Cracked Pins = 14
Let E2 = The Probability That A Bad Pin Is Accepted
Let P2 = The Probability That A Bad Pin Is Rejected

	Identified Defective	Identified Defective Actually Defective	E2	P2
Member 1	10	7	7/14 = .500	7/14 = .500
Member 2	13	11	3/14 = .214	11/14 = .786
Member 3	9	9	5/14 = .357	9/14 = .643
Member 4	9	8	6/14 = .429	8/14 = .571
Member 5	9	8	6/14 = .429	8/14 = .571

Left Hand Side

Sample Size = 156 track pins
Actual Number of Cracked Pins = 7
Let E2 = The Probability That A Bad Pin Is Accepted
Let P2 = The Probability That A Bad Pin Is Rejected

	Identified Defective	Identified Defective Actually Defective	E2	P2
Member 1	7	4	3/7 = .429	4/7 = .571
Member 2	5	3	4/7 = .571	3/7 = .429
Member 3	8	3	4/7 = .571	3/7 = .429
Member 4	3	2	5/7 = .714	2/7 = .286
Member 5	3	1	6/7 = .857	1/7 = .143

Table 3 4. Probability Data Summation For the Entire Population of Ultrasonic Test Data.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The hammer ring test evaluation at the Keweenaw Research Center did not prove to be an effective testing procedure for cracked track pins. The data recorded and its analysis shows that the hammer ring test is inaccurate, inconsistent and a high-cost risk if it were solely relied upon. Therefore, it is the recommendation of TARDEC's Track Technology branch that the hammer ring test not be put back into the Army Safety Manual.

The ultrasonic sound detection system used by the group provided better results for locating cracked pins. The data and the analysis of the ultrasonic equipment may have proven it to be a realistic consideration for future track inspection. One recommedation is to investigate a new, more practical design. For example, an ultrasonic detection device which would be read like a go/no go gage. The operator would simply apply the tranducer portion to the track pin and read the crack or no crack signal. The Track Technology group and the Keweenaw Research Center would be interested in applying their ultrasonic testing experience into any future testing research desired by the Tank-Automotive Command.

APPENDIX A

Right Side Cracked Pin Detection Test

Pitch #		Master	Hammer Ring Test Member 1	Member 2	Member3	Member 4	Member 5
1	a	N	N	N	N	N	N
	b	N	Yes	Yes	Yes	Yes	N
2	a	N	N	Yes	Yes	Yes	Yes
	b	N	Yes	N	N	N	N
3	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
4	a	N	N	N	N	N	Yes
	b	N	N	N	N	N	N
5	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
6	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
7	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
8	a	N	N	N	N	N	N
	b	N	N	Yes	N	N	N
9	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
10	a	Yes	N	N	N	N	N
	b	N	N	N	N	N	N
11	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
12	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
13	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
14	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
15	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
16	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
17	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
18	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
19	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
20	a	N	N	N	Yes	N	N
	b	N	N	N	N	N	N
21	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
22	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
23	a	N	Yes	N	N	N	N
	b	N	N	Yes	Yes	N	N
24	a	N	Yes	Yes	Yes	N	Yes
	b	N	N	N	N	N	N

Right Side Cracked Pin Detection Test

Pitch #	Master	Hammer Ring Test Member 1	Member 2	Member3	Member 4	Member 5
25 a	N	N	N	N	N	N
b	Yes	N	N	N	N	N
26 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	N
27 a	Yes	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
28 a	N	N	N	N	N	N
b	N	N	N	N	N	N
29 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	N
30 a	N	Yes	Yes	Yes	Yes	Yes
b	Yes	N	N	N	N	N
31 a	N	N	N	Yes	N	N
b	Yes	N	N	N	N	N
32 a	N	N	N	N	N	N
b	N	N	N	N	N	N
33 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
34 a	Yes	Yes	Yes	Yes	Yes	Yes
b	N	N	Yes	N	N	N
35 a	Yes	N	Yes	N	N	N
b	N	N	N	N	N	N
36 a	N	N	N	N	N	N
b	N	N	N	N	N	N
37 a	N	N	N	N	N	N
b	N	N	N	N	N	N
38 a	N	N	N	N	N	N
b	N	N	N	N	N	N
39 a	N	N	N	N	N	N
b	N	N	N	N	N	N
40 a	N	N	N	N	N	N
b	N	N	N	Yes	N	Yes
41 a	N	Yes	Yes	Yes	N	Yes
b	N	N	N	N	N	N
42 a	N	N	N	N	N	N
b	Small	N	N	N	N	N
43 a	N	N	N	N	N	N
b	N	N	N	N	N	N
44 a	N	N	N	N	N	N
b	N	N	N	N	N	N
45 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
46 a	N	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
47 a	N	N	N	N	N	N
b	Yes	N	N	N	N	N
48 a	N	N	N	N	N	N
b	N	N	Yes	N	N	N

Right Side Cracked Pin Detection Test

Pitch #	Master	Hammer Ring Test Member 1	Member 2	Member3	Member 4	Member 5
49 a	N	N	Yes	N	N	N
b	N	N	N	N	N	Yes
50 a	N	N	N	N	N	N
b	N	N	N	N	N	N
51 a	N	N	N	N	N	N
b	N	N	N	N	N	N
52 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
53 a	N	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
54 a	N	N	N	N	N	N
b	N	N	Yes	Yes	Yes	Yes
55 a	N	N	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
56 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
57 a	N	N	N	N	N	N
b	N	N	N	N	N	Yes
58 a	N	N	N	N	N	N
b	N	N	N	N	N	N
59 a	N	N	N	N	N	N
b	N	N	N	N	N	N
60 a	N	N	N	N	N	N
b	N	N	N	N	N	N
61 a	N	N	N	N	N	N
b	N	N	N	N	N	N
62 a	N	N	N	N	N	N
b	N	N	N	N	N	N
63 a	N	N	N	N	N	N
b	N	N	N	N	N	N
64 a	N	N	N	N	N	N
b	N	N	N	N	N	N
65 a	N	N	N	N	N	N
b	N	N	N	N	N	N
66 a	N	N	N	N	N	N
b	N	N	Yes	Yes	N	Yes
67 a	N	N	Yes	Yes	N	N
b	N	N	Yes	Yes	N	N
68 a	N	N	Yes	Yes	N	N
b	N	N	N	N	N	Yes
69 a	N	N	N	N	N	N
b	N	N	N	N	N	Yes
70 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
71 a	Yes	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
72 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N

Right Side Cracked Pin Detection Test

Pitch #	Master	Hammer Ring Test Member 1	Member 2	Member3	Member 4	Member 5
73 a	N	N	N	N	N	N
b	N	N	N	N	N	N
74 a	N	N	N	N	N	N
b	N	N	N	N	N	N
75 a	N	N	N	N	N	N
b	N	N	N	N	N	N
76 a	N	N	N	N	N	N
b	N	N	N	N	N	N
77 a	N	N	N	N	N	N
b	N	N	N	N	N	N
78 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side Cracked Pin Detection Test

Pitch #		Master	Hammer Ring Test Member 1	Member 2	Member 3	Member 4	Member 5
1	a	N	N	N	N	N	N
	b	N	N	Yes	N	N	Yes
2	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
3	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
4	a	N	N	N	N	N	N
	b	N	Yes	N	Yes	N	N
5	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
6	a	N	N	N	N	N	N
	b	N	N	Yes	N	N	N
7	a	N	Yes	Yes	N	N	N
	b	N	N	N	N	N	N
8	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
9	a	N	N	N	N	N	N
	b	N	Yes	Yes	N	N	N
10	a	N	Yes	Yes	N	N	N
	b	N	Yes	Yes	Yes	Yes	Yes
11	a	N	Yes	Yes	Yes	Yes	Yes
	b	N	N	N	N	N	N
12	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
13	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
14	a	Yes	N	N	N	N	N
	b	N	N	N	N	N	N
15	a	N	N	N	N	N	Yes
	b	N	N	N	N	N	N
16	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
17	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
18	a	N	N	N	Yes	N	N
	b	N	N	N	N	N	N
19	a	N	N	N	N	N	N
	b	N	N	N	Yes	N	N
20	a	N	N	N	Yes	N	N
	b	N	N	N	Yes	N	N
21	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
22	a	N	N	N	N	N	N
	b	Possible	N	N	N	N	N
23	a	Possible	N	N	N	N	N
	b	N	N	N	N	N	N
24	a	N	N	N	N	N	N
	b	N	N	N	N	N	N

Left Side Cracked Pin Detection Test

Pitch #	Master	Hammer Ring Test Member 1	Member 2	Member 3	Member 4	Member 5
25 a	N	N	N	N	N	N
b	N	N	Yes	N	N	N
26 a	N	N	Yes	N	N	N
b	N	N	N	N	N	N
27 a	N	Yes	N	N	N	N
b	N	N	N	N	N	N
28 a	N	N	N	N	N	N
b	N	Yes	N	N	N	N
29 a	N	N	N	N	N	Yes
b	Yes	N	N	N	N	N
30 a	N	N	N	N	N	N
b	N	N	N	N	N	N
31 a	N	N	N	N	N	N
b	N	N	N	N	N	N
32 a	N	N	N	N	N	N
b	N	N	N	N	N	N
33 a	N	N	N	Yes	N	N
b	N	N	N	N	N	N
34 a	N	N	N	N	N	N
b	N	N	N	N	N	N
35 a	N	N	N	N	N	N
b	N	N	N	N	N	N
36 a	N	N	N	N	N	N
b	N	N	N	N	N	N
37 a	N	N	N	N	N	Yes
b	N	N	N	N	N	N
38 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
39 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
40 a	N	N	N	N	N	N
b	N	N	N	N	N	N
41 a	N	Yes	N	N	N	N
b	N	N	N	N	N	N
42 a	N	N	N	N	N	N
b	N	N	N	N	N	N
43 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
44 a	N	Yes	Yes	Yes	Yes	N
b	N	N	N	N	N	N
45 a	N	N	N	N	N	N
b	N	N	N	N	N	N
46 a	N	N	N	N	N	N
b	N	N	N	N	N	N
47 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
48 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side

Cracked Pin Detection Test

Hammer Ring Test

Pitch #	Master	Member 1	Member 2	Member 3	Member 4	Member 5
49 a	N	N	N	N	N	N
b	N	N	N	N	N	N
50 a	N	N	N	N	N	N
b	N	N	N	N	N	N
51 a	N	N	N	N	N	Yes
b	N	N	N	N	N	N
52 a	N	N	N	N	N	N
b	N	N	N	N	N	N
53 a	N	N	Yes	N	N	N
b	N	N	N	N	N	N
54 a	N	N	N	N	N	N
b	N	N	N	N	N	N
55 a	N	N	N	N	N	N
b	N	N	Yes	N	N	N
56 a	N	N	N	N	N	N
b	N	N	N	N	N	N
57 a	N	N	N	N	N	N
b	N	N	N	N	N	N
58 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
59 a	N	N	N	N	N	N
b	N	N	N	N	N	N
60 a	N	N	N	N	N	N
b	N	N	N	N	N	N
61 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
62 a	N	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
63 a	N	N	N	N	N	N
b	N	N	N	N	N	N
64 a	N	N	N	N	N	N
b	N	N	N	N	N	N
65 a	N	N	N	N	N	N
b	N	N	N	N	N	N
66 a	N	N	N	N	N	Yes
b	N	N	N	N	N	N
67 a	N	N	N	N	N	N
b	N	Yes	Yes	Yes	Yes	Yes
68 a	N	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
69 a	N	N	N	N	N	N
b	N	N	N	N	N	N
70 a	N	N	N	N	N	N
b	N	N	N	N	N	N
71 a	N	N	N		N	N
b	N	N	N		N	N
72 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side Cracked Pin Detection Test

Pitch #	Master	Hammer Ring Test Member 1	Member 2	Member 3	Member 4	Member 5
73 a	N	N	N	N	N	N
b	N	N	N	N	N	N
74 a	N	N	N	N	N	N
b	N	N	N	N	N	N
75 a	N	N	N	N	N	N
b	N	N	N	N	N	N
76 a	N	N	N	N	N	N
b	N	N	N	N	N	N
77 a	N	N	N	N	N	N
b	N	N	N	N	N	N
78 a	N	N	N	N	N	N
b	N	N	N	N	N	N

APPENDIX B

Right Side Cracked Pin Detection Test

Pitch #		Ultrasonics Test Master	Member 1	Member 2	Member 3	Member 4	Member 5
1	a	N	N	N	N	N	N
	b	N	N	Yes	N	N	N
2	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
3	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
4	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
5	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
6	a	N	N	N	N	N	N
	b	N	N	N	N	Yes	N
7	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
8	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
9	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
10	a	Yes	N	N	N	N	N
	b	N	N	N	N	N	N
11	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
12	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
13	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
14	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
15	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
16	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
17	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
18	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
19	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
20	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
21	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
22	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
23	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
24	a	N	N	N	N	N	N
	b	N	Yes	Yes	N	N	N

Right Side Cracked Pin Detection Test

Pitch #	Master	Ultrasonic Test Member 1	Member 2	Member 3	Member 4	Member 5
25 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
26 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
27 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
28 a	N	N	N	N	N	N
b	N	N	N	N	N	N
29 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
30 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
31 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	N	N
32 a	N	N	N	N	N	N
b	N	N	N	N	N	N
33 a	N	N	N	N	N	N
b	N	N	N	N	N	N
34 a	Yes	Yes	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
35 a	Yes	N	Yes	Yes	Yes	Yes
b	N	N	N	N	N	N
36 a	N	N	N	N	N	N
b	N	N	N	N	N	N
37 a	N	N	N	N	N	N
b	N	N	N	N	N	N
38 a	N	N	N	N	N	N
b	N	N	N	N	N	N
39 a	N	N	N	N	N	N
b	N	N	N	N	N	N
40 a	N	N	N	N	N	N
b	N	N	N	N	N	N
41 a	N	N	N	N	N	N
b	N	N	N	N	N	N
42 a	N	N	N	N	N	N
b	Small	N	Yes	N	N	N
43 a	N	N	N	N	N	N
b	N	N	N	N	N	N
44 a	N	N	N	N	N	N
b	N	N	N	N	N	N
45 a	N	N	N	N	N	N
b	N	N	N	N	N	N
46 a	N	N	N	N	N	N
b	N	N	N	N	N	N
47 a	N	N	N	N	N	N
b	Yes	N	Yes	Yes	Yes	Yes
48 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Right Side Cracked Pin Detection Test

Pitch #		Ultrasonics Test Master	Member 1	Member 2	Member 3	Member 4	Member 5
49	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
50	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
51	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
52	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
53	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
54	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
55	a	N	N	N	N	N	N
	b	N	Yes	N	N	N	N
56	a	Yes	N	Yes	N	Yes	Yes
	b	N	N	N	N	N	N
57	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
58	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
59	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
60	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
61	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
62	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
63	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
64	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
65	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
66	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
67	a	N	N	N	N	N	N
	b	N	Yes	N	N	N	N
68	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
69	a	N	N	N	N	N	N
	b	N	N	N	N	N	Yes
70	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
71	a	Yes	Yes	Yes	Yes	N	N
	b	N	N	N	N	N	N
72	a	Yes	N	N	N	N	N
	b	N	N	N	N	N	N

Right Side Cracked Pin Detection Test

Pitch #	Master	Ultrasonics Test Member 1	Member 2	Member 3	Member 4	Member 5
73 a	N	N	N	N	N	N
b	N	N	N	N	N	N
74 a	N	N	N	N	N	N
b	N	N	N	N	N	N
75 a	N	N	N	N	N	N
b	N	N	N	N	N	N
76 a	N	N	N	N	N	N
b	N	N	N	N	N	N
77 a	N	N	N	N	N	N
b	N	N	N	N	N	N
78 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side Cracked Pin Detection Test

Pitch #		Ultrasonics Test					
		Master	Member 1	Member 2	Member 3	Member 4	Member 5
1	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
2	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
3	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
4	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
5	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
6	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
7	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
8	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
9	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
10	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
11	a	N	Yes	N	N	N	Yes
	b	N	N	N	N	N	N
12	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
13	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
14	a	Yes	Yes	N	N	N	N
	b	N	N	N	N	N	Yes
15	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
16	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
17	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
18	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
19	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
20	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
21	a	N	N	N	N	N	N
	b	N	N	N	N	N	N
22	a	N	N	N	N	N	N
	b	Possible	N	N	Yes	N	N
23	a	Possible	N	N	N	N	N
	b	N	N	N	N	N	N
24	a	N	N	N	N	N	N
	b	N	N	N	N	N	N

Left Side

Cracked Pin Detection Test

Ultrasonics Test

Pitch #	Master	Member 1	Member 2	Member 3	Member 4	Member 5
25 a	N	N	N	N	N	N
b	N	N	N	N	N	N
26 a	N	N	N	N	N	N
b	N	N	N	N	N	N
27 a	N	N	N	N	N	N
b	N	N	N	N	N	N
28 a	N	N	N	N	N	N
b	N	N	N	N	N	N
29 a	N	N	N	N	N	N
b	Yes	N	N	Yes	N	N
30 a	N	N	N	N	N	N
b	N	N	N	N	N	N
31 a	N	N	N	N	N	N
b	N	N	N	N	N	N
32 a	N	N	N	N	N	N
b	N	N	N	N	N	N
33 a	N	N	N	N	N	N
b	N	N	N	N	N	N
34 a	N	N	N	N	N	N
b	N	N	N	N	N	N
35 a	N	N	N	N	Yes	N
b	N	N	N	N	N	N
36 a	N	N	N	N	N	N
b	N	N	N	N	N	N
37 a	N	N	N	N	N	N
b	N	N	N	Yes	N	N
38 a	Yes	Yes	Yes	N	N	N
b	N	N	N	Yes	N	N
39 a	Yes	N	N	N	N	N
b	N	N	N	N	N	N
40 a	N	N	N	N	N	N
b	N	N	N	N	N	N
41 a	N	N	N	N	N	N
b	N	N	N	N	N	N
42 a	N	N	N	N	N	N
b	N	N	N	N	N	N
43 a	N	N	N	N	N	N
b	Yes	Yes	Yes	Yes	Yes	Yes
44 a	N	N	N	N	N	N
b	N	N	N	N	N	N
45 a	N	N	N	N	N	N
b	N	N	N	N	N	N
46 a	N	N	N	N	N	N
b	N	N	N	N	N	N
47 a	Yes	N	N	N	Yes	N
b	N	N	N	N	N	N
48 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side Cracked Pin Detection Test

Ultrasonics Test

Pitch #	Master	Member 1	Member 2	Member 3	Member 4	Member 5
49 a	N	N	N	N	N	N
b	N	N	N	N	N	N
50 a	N	N	N	N	N	N
b	N	N	N	N	N	N
51 a	N	N	N	N	N	N
b	N	N	N	N	N	N
52 a	N	N	N	N	N	N
b	N	N	N	N	N	N
53 a	N	N	N	N	N	N
b	N	N	N	N	N	N
54 a	N	N	N	N	N	N
b	N	N	N	N	N	N
55 a	N	N	N	N	N	N
b	N	N	N	N	N	N
56 a	N	N	N	N	N	N
b	N	N	N	N	N	N
57 a	N	N	N	N	N	N
b	N	N	N	N	N	N
58 a	Yes	Yes	Yes	Yes	N	N
b	N	N	N	N	N	N
59 a	N	N	Yes	N	N	N
b	N	N	N	N	N	N
60 a	N	N	N	N	N	N
b	N	N	N	N	N	N
61 a	N	N	N	N	N	N
b	N	N	N	N	N	N
62 a	N	N	N	N	N	N
b	N	Yes	N	N	N	N
63 a	N	N	N	N	N	N
b	N	N	N	N	N	N
64 a	N	N	N	N	N	N
b	N	N	N	N	N	N
65 a	N	N	N	N	N	N
b	N	N	N	N	N	N
66 a	N	N	Yes	N	N	N
b	N	N	N	N	N	N
67 a	N	N	N	N	N	N
b	N	Yes	N	N	N	N
68 a	N	N	N	N	N	N
b	N	N	N	N	N	N
69 a	N	N	N	N	N	N
b	N	N	N	N	N	N
70 a	N	N	N	N	N	N
b	N	N	N	N	N	N
71 a	N	N	N	N	N	N
b	N	N	N	N	N	N
72 a	N	N	N	N	N	N
b	N	N	N	N	N	N

Left Side — Cracked Pin Detection Test

Pitch #	Master	Ultrasonics Test Member 1	Member 2	Member 3	Member 4	Member 5
73 a	N	N	N	N	N	N
b	N	N	N	N	N	N
74 a	N	N	N	Yes	N	N
b	N	N	N	N	N	N
75 a	N	N	N	N	N	N
b	N	N	N	N	N	N
76 a	N	N	N	N	N	N
b	N	N	N	N	N	N
77 a	N	N	N	Yes	N	N
b	N	N	N	N	N	N
78 a	N	N	N	N	N	N
b	N	N	N	N	N	N

DISTRIBUTION LIST

	Copies
Commander Defense Technical Information Center Bldg. 5, Cameron Station ATTN: DDAC Alexandria, VA 22304-9990	2
Manager Defense Logistics Studies Information Exchange ATTN: AMXMC-D Fort Lee, VA 23801-6044	2
Commander U.S. Army Tank-Automotive Command ATTN: ASQNC-TAC-DIT (Technical Library) Warren, MI 48397-5000	2
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-CF (Dr. Oscar) Warren, MI 48397-5000	1
Director U.S. Army Materiel Systems Analysis Activity ATTN: AMXSY-MP (Mr. Cohen) Aberdeen Proving Ground, MD 21005-5071	1
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-RT (Mr. Kaifesh) Warren, MI 48397-5000	1
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-RTT (Mr. Szakacs) Warren, MI 48397-5000	2
Commander U.S. Army Tank-Automotive Command ATTN: AMSTA-CVC (Mr. Laurain) Warren, MI 48397-5000	1